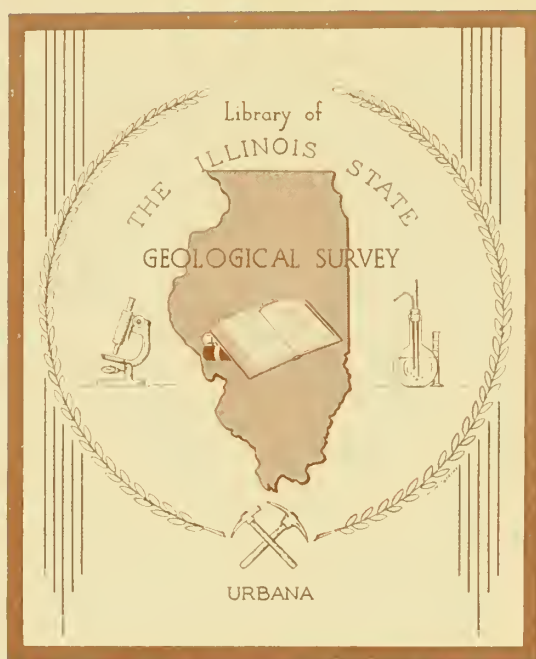






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ENVIRONMENTAL GEOLOGY NOTES

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GEOLOGICAL AND GEOPHYSICAL
INVESTIGATIONS FOR
A GROUND-WATER SUPPLY
AT MACOMB, ILLINOIS

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FOREWORD

"Environmental Geology Notes" are information releases published by the Illinois State Geological Survey to report applications of geologic knowledge to problems of the human environment. Geologic information is applicable to a broad range of activities, including construction of buildings, transportation, and utility facilities; development and management of water and mineral resources; safe disposal of wastes; and land-use planning.

To serve such a broad range of activities, reports on many different subjects are included in this series. This report describes a typical geologic-geophysical study made by the Survey in connection with a municipal water-supply problem.

GEOLOGICAL AND GEOPHYSICAL INVESTIGATIONS FOR

A GROUND-WATER SUPPLY AT MACOMB, ILLINOIS

Keros Cartwright and David A. Stephenson

The need for a supplemental, economical ground-water supply for the city of Macomb, McDonough County, during the 1964 drought instigated a geologic-geophysical study by the Illinois State Geological Survey of an 80-acre site in the LaMoine River Valley. Twenty-eight test holes drilled by the city provided control for geological and geophysical interpretations. The drilling and geophysical data were used to delineate an alluvial aquifer system, but it was judged inadequate for the required water supply.

Data from MD-1 hammer seismograph and earth resistivity profiles were of limited use without adequate subsurface control.

INTRODUCTION

Securing a ground-water supply for a municipality or industry is a complex procedure involving many types of problems—geological, economic, engineering, and management. The Illinois State Geological Survey, acting in an advisory capacity, provides geological information on the occurrence and general characteristics of the local aquifers—the rocks or unconsolidated strata that will yield water to wells. In some cases it also conducts geophysical surveys to help locate or evaluate the aquifers.

The aspects of water-supply development and maintenance that involve economics, engineering, or management are the responsibility of the municipality or industry seeking water, although the Geological Survey may provide assistance on some facets of these problems. The municipality or industry is responsible, preferably through an experienced engineering consultant, for planning and supervising the test drilling programs that frequently are necessary in ground-water investigations; for maintaining proper records of all test borings and wells, including strata penetrated, well construction methods, water levels, and pumpage; for analyzing the engineering and economic aspects of the water-supply scheme or alternatives; and for constructing and managing the water-supply development in accordance with established geologic and hydrologic conditions. Unless such records are kept, State agencies encounter difficulties when they attempt to assist the cities in solving water supply problems.

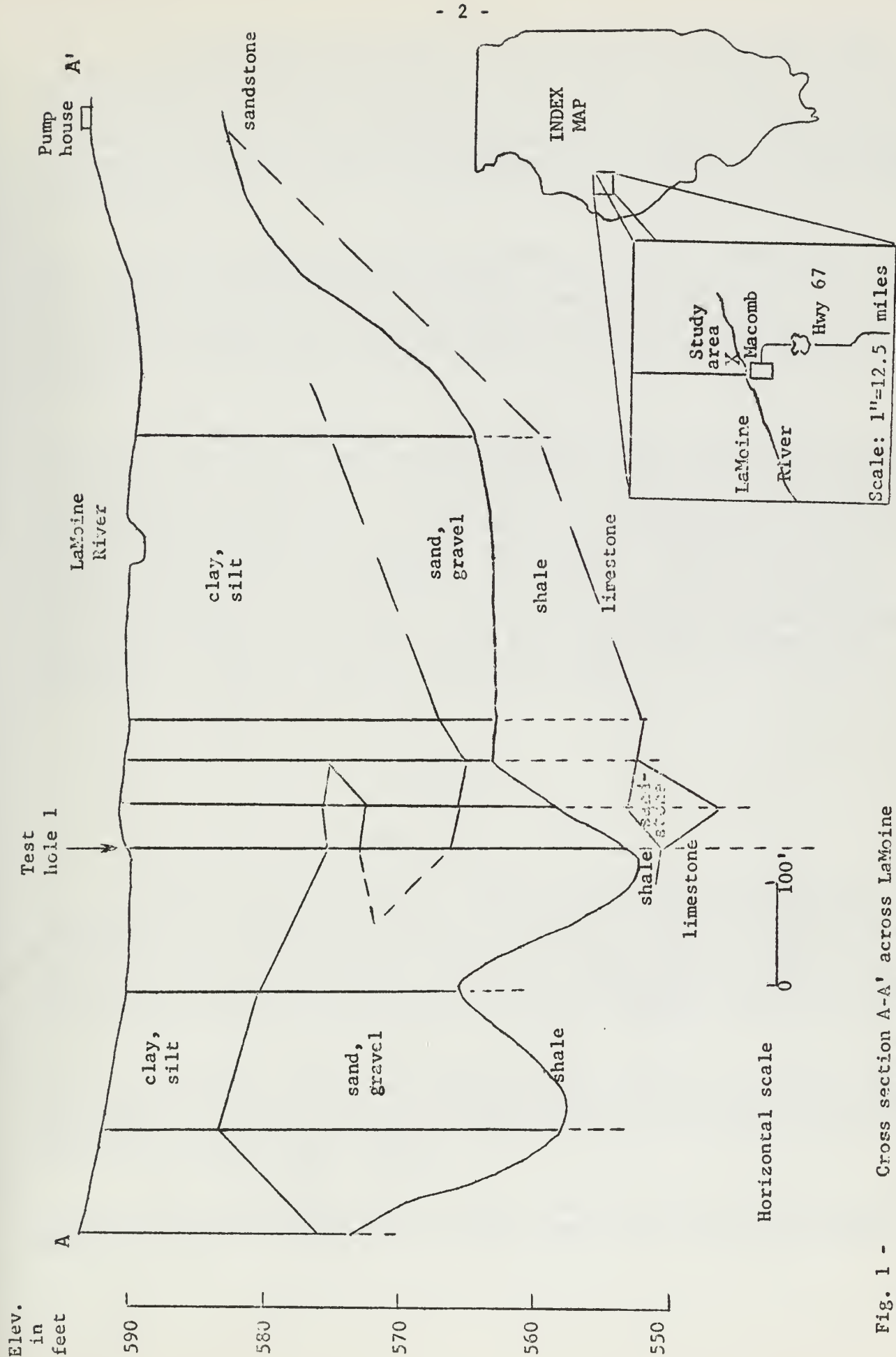


Fig. 1 - Cross section A-A' across LaMoine River floodplain near Macomb. Vertical lines are test holes. Line of cross section is shown in figure 3.

A typical Geological Survey ground-water investigation was carried out for the city of Macomb, McDonough County, Illinois. Geological and geophysical exploration was first started in 1943 (Buhle, 1948, 1956). The water supply for the city is from reservoirs on tributary creeks and directly from the LaMoine River, but a ground-water source has been sought at various times to supplement this supply, especially during periods of drought. The early studies concentrated on areas south of the city and covered the area north of the city only briefly.

Severe drought conditions occurred in the summer of 1964, and the city again sought an economical source of ground water. The areas explored in previous studies were too far from the city for consideration; however, as one of the earlier studies had indicated that there might be water-bearing sand and gravel in the LaMoine River floodplain (fig. 1), eight test holes were drilled by the city and a pumping test made in the valley near the present water-plant intake.

The samples and drillers logs studied by the Geological Survey indicated that a series of seismic profiles might help define the shape of the bedrock surface in the area, but the seismic and earlier resistivity data proved to be inconclusive. However, information from drillers logs, sample studies, and geophysical surveys was used to determine the approximate size, shape, and hydrogeologic boundaries of the aquifer so that the sustained yield of the aquifer could be estimated (Stephenson and Cartwright, 1964). To define the aquifer in detail, 20 more test borings were made, which generally confirmed the first estimates and conclusions concerning the aquifer. A hydrologic analysis of the aquifer, made by the Illinois State Water Survey (Walker, 1964), indicated that the site could not produce enough water to fill the minimum requirements (1.5 million gallons per day) of the city.

HYDROGEOLOGY

General Geology

The surficial deposits of the Macomb region are Illinoian glacial drift, loess, and alluvial sediments. The alluvial material in the study area was deposited by an aggrading stream that previously had cut a channel into bedrock. The valley-fill materials grade upward from relatively coarse material at the base to finer sediments, reflecting the decreasing velocity of the LaMoine River flow. The upper portion of the fill, between 8 and 24 feet thick, contains fine sands and silts typical of floodplain deposition (figs. 1, 2).

Beneath the basal sand and gravel of the alluvium is shale of Pennsylvanian age, underlain in turn by the Mississippian Keokuk and Burlington Formations, which are cherty limestones. Because of low permeabilities and possible deleterious water quality, the bedrock formations were not considered as a source for the Macomb water supply.

The cross sections (figs. 1, 2) and bedrock surface map (fig. 3) were constructed from interpretations of drillers logs, well cuttings, and hammer-seismograph data.

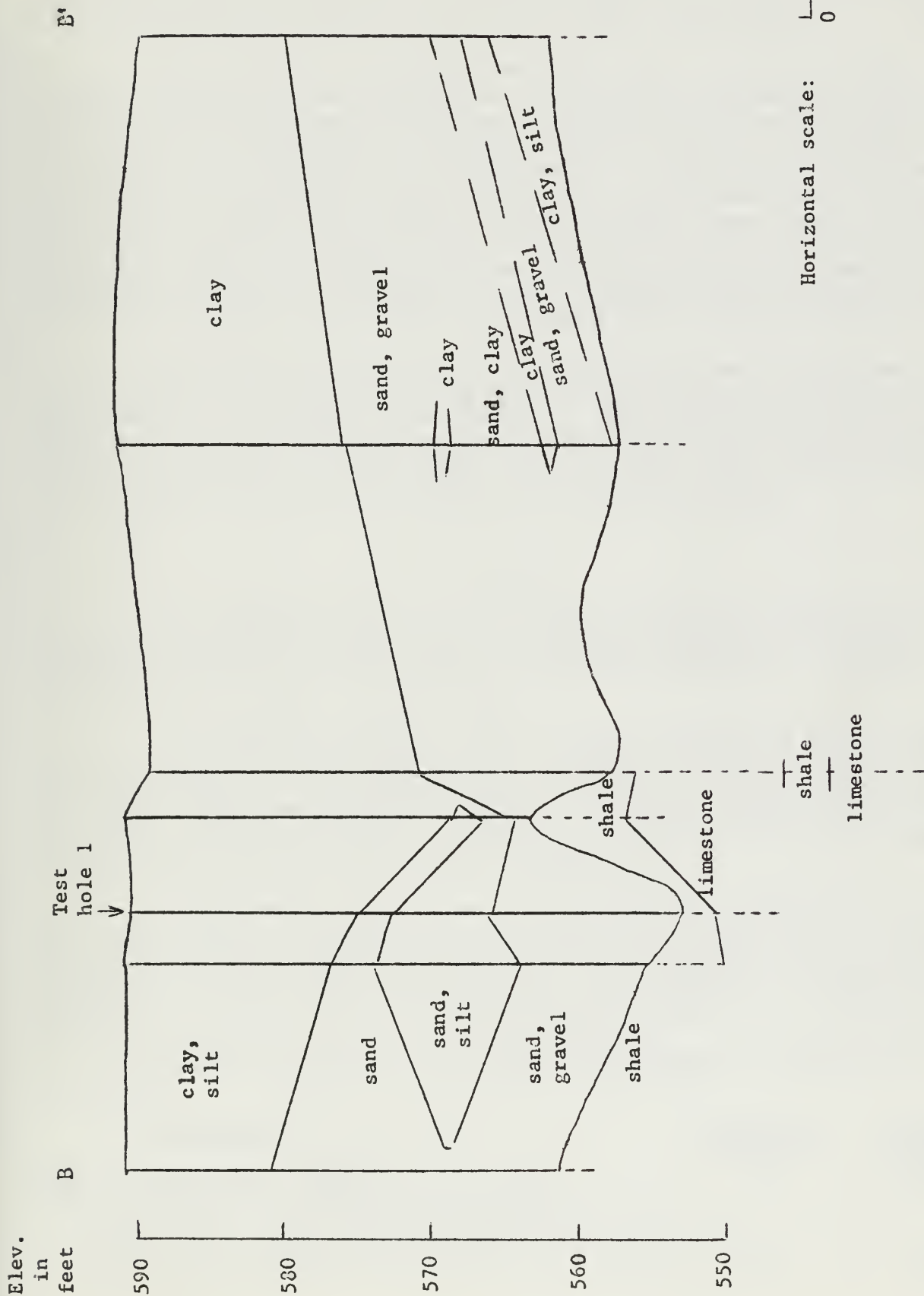


Fig. 2 - Cross section B-B' along LaMoine River floodplain near Macomb. Line of cross section is shown in figure 3. Vertical lines are test holes.

Bedrock Topography

The bedrock surface of the study area forms a small linear basin, 750 to 1000 feet wide, that is oriented approximately east-west, and has a maximum relief of 25 feet (fig. 3). The basin outlet is a narrow channel at the side, approximately 500 feet north of the present LaMoine River.

The thickness of permeable materials within the basin varies. The bedrock surface rises to the north and to the south, and there is a small rise in the center of the basin. The rise is substantiated by subsurface data and may result from differences in bedrock lithology as well as from complex erosional history. The south part of the basin is a fairly flat bench below an elevation of approximately 565 feet (fig. 1), part of which underlies the La Moine River. South of the river the bedrock surface rises rapidly. The bedrock encountered at foundation depth at the filter plant pump house was described as sandstone by Patrick Tiernan, Macomb City Engineer, (personal communication, 1964). Correlation between subsurface data and seismic data in defining the bedrock rise south of the LaMoine River was good (fig. 1).

The bedrock valley beneath the LaMoine River may be a product of post-Illinoian erosion, for glacial drift of Illinoian age mantles the surrounding uplands but is absent in the study area. The Pleistocene ancestral LaMoine River may have cut a channel through the drift into bedrock during Sangamonian and/or Wisconsinan time; with decrease in the volume of the river to its present stage, aggradation of progressively finer materials occurred.

Alluvium

The lower half of the unconsolidated alluvial fill within the bedrock basin is mainly sand or gravel and is considered an aquifer. The upper portion is silt or sandy silt and clay and is considered an aquitard—a stratum that restricts the movement of ground water.

The permeable deposits thin to the east, south, and north of the study area and become too thin to yield significant amounts of water; to the west, development of the aquifer would be limited by the presence of a sanitary landfill. The maximum thickness of 25 feet is attained by the aquifer along the axis of the bedrock valley; its average thickness is 10 feet and average width 750 feet within the area shown in figure 3.

In the central part of the basin, the aquifer is divided into upper and lower members by a minor aquitard, a lens of silty sand (figs. 1 and 2). Both upper and lower members are saturated. Probably no direct hydrologic continuity exists between the aquifer and the river; therefore, vertical recharge is slow and is controlled by the vertical permeability of the silty upper aquitard.

A sample study log of test hole 1 illustrates the sequence of alluvial deposits.

<u>Lithology</u>	<u>Thickness</u> (ft)	<u>Depth</u> (ft)
Silt, noncalcareous, brown.....	5	0-5
Silt, micaceous, noncalcareous, yellow-brown, oxidized; some fine- to medium-grained, subrounded to rounded quartz grains.....	10	5-15

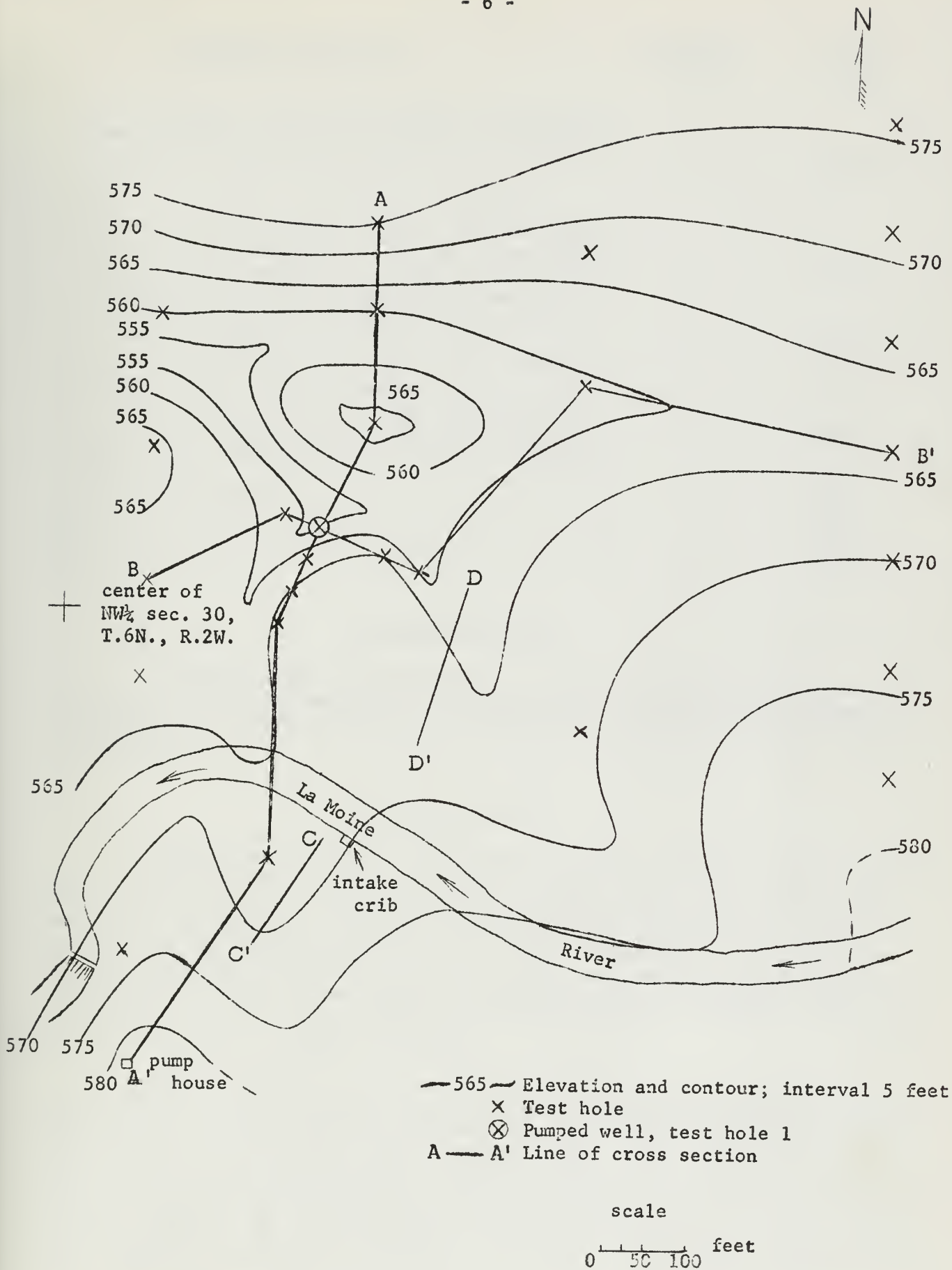


Figure 3. - Bedrock topography of study area.

<u>Lithology</u> (continued)	<u>Thickness</u> (ft)	<u>Depth</u> (ft)
Sand, quartzose, tan, noncalcareous, predominantly fine to medium grained, subrounded to rounded, clean.....	2	15-17
Silt, sandy, clayey, calcareous, dark gray; and		
Sand, silty, noncalcareous, brown, fine to medium grained; chert fragments. (May be alternating layers of silt and sand, or sand may be slump.)..	7	17-24
Sand, silty, quartzose, calcareous, brown to tan, predominantly fine to medium grained, sub- rounded to rounded.....	3	24-27
Sand, gravelly, calcareous; sand fine to medium grained; gravel fine to medium.....	5	27-32
Sand and gravel, similar to layer above but with more gravel up to several inches in diameter.....	3	32-35
Gravel, sandy; diameter up to 3/4-inch, averaging 1/8-inch.....	2	35-37
"Shale," sample missing.....	2	37-39
Chert.....	6	39-45
Chert and shale.....	5	45-50
Chert.....	13	50-63

GEOPHYSICAL SURVEYS

Electrical earth resistivity and seismic profiles were made on the floodplain of the LaMoine River. Both geophysical surveys posed problems in interpretation and were of limited use without a considerable amount of geologic control.

Resistivity Survey

Resistivity values on the floodplain and on a terrace-like feature on the south side of the river are considerably higher than on the upland till plain. A series of resistivity stations extending across the valley averaged about 5000 ohm-centimeters higher than those on the surrounding till plain. However, the resistivity depth profiles showed a featureless curve that continued increasing throughout its entire length, and the highest resistivity values were obtained at the maximum electrode spacing (the greatest depth of penetration of the electric field). The depth of highly resistive earth material was therefore not clearly indicated.

In the Macomb area, limestone and sandstone in the bedrock and sand in the drift are the principal materials that can cause high resistivity readings. It was at first assumed that the principal cause of these high readings was sand in the valley fill, because no persistent sandstones or limestones were known in the shallow bedrock. However, results of the drilling showed the top of the Mississippian-age limestone was much higher than had been thought, and they suggest that the limestone is the principal material of high resistance encountered. However, the thin, unconsolidated sand and the shallow bedrock sandstone probably also contribute to the high resistivity values obtained.

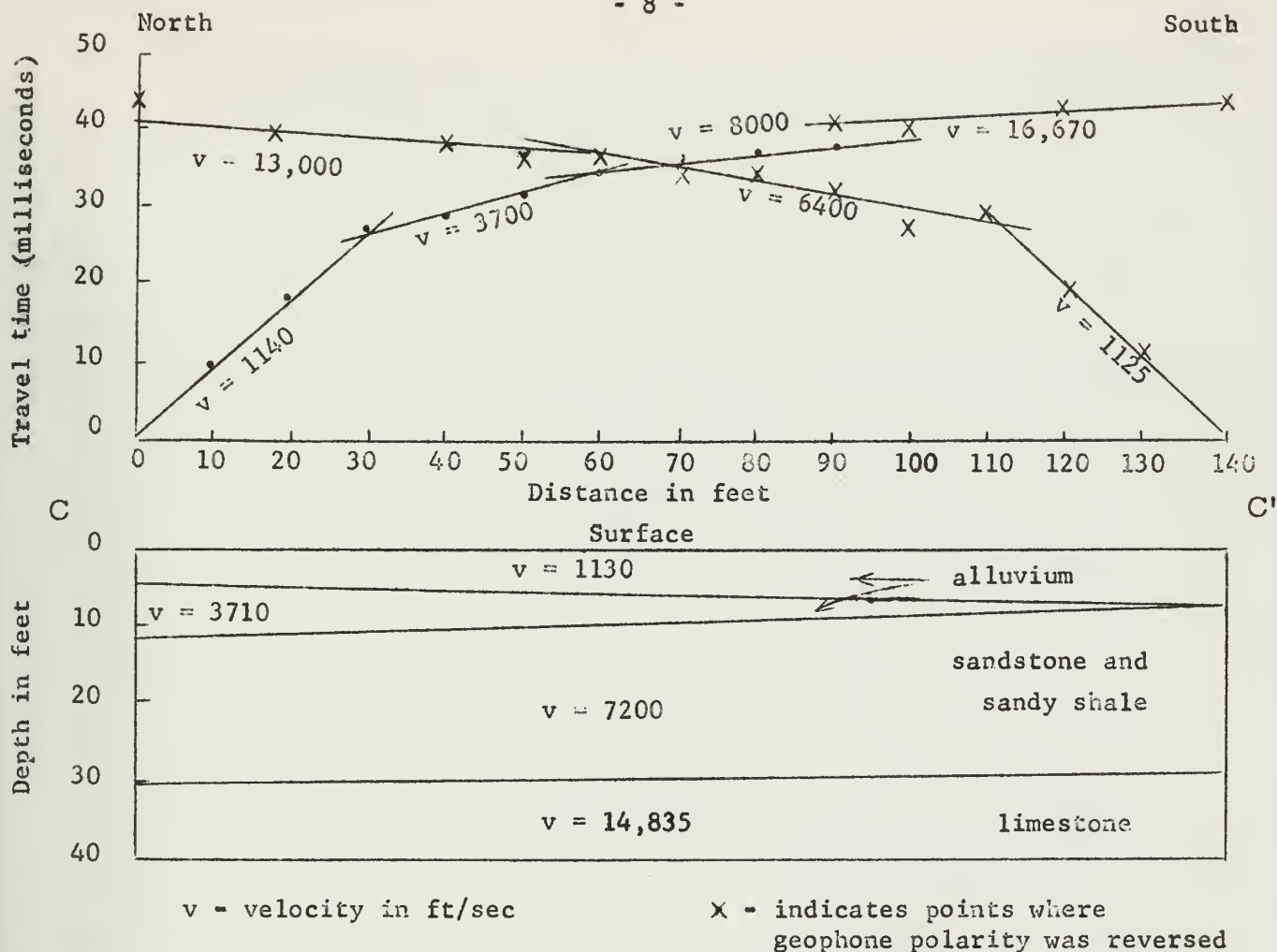


Fig. 4 - Seismic profile of area south of the LaMoine River and interpretation. Line of cross section is shown in figure 3.

Seismic Survey

Three seismic profiles were made with an MD-1 hammer seismograph. Interpretation of the results presented several difficulties that limited the usefulness of the data. The first problem was detecting the first arrival of the shock wave in the "weathered layer," a surficial, low velocity layer. The relationship of this layer to the geologic weathered layer is not fully understood (McGinnis and Kempton, 1961). In all cases, the instrument recorded as first arrival the air-coupled ground wave rather than that for the earth material itself. In interpreting results we corrected this first arrival by cutting the calculated depth to the first velocity interface (base of "weathered layer") by half, as suggested by Lennox (1962). This correction worked well when checked against drilling records.

The second difficulty encountered was that the bedrock surface did not act as a seismic reflecting surface in two of the three profiles. The top of the Mississippian-age limestone, not the top of the Pennsylvanian rocks, was the first rock surface giving a return. There are two possible explanations for this. The first is the lack of a sufficiently large velocity difference between the Pennsylvanian shale and the overlying sand and gravel of the valley

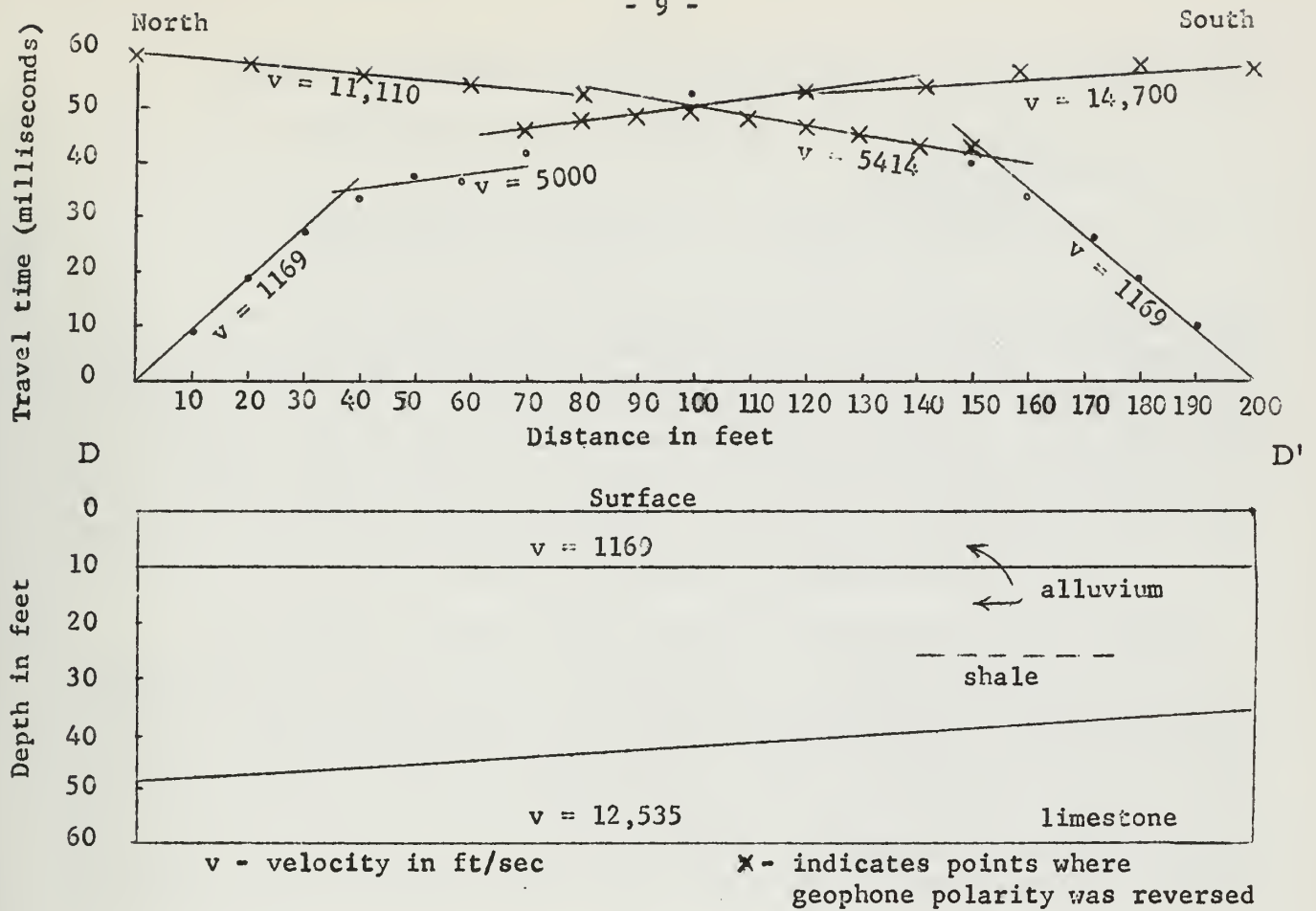


Fig. 5 - Seismic profile of area north of the LaMoine River and interpretation. Line of cross section is shown in figure 3.

fill. The second is that the shale was too thin in comparison to the wave length of the shock wave to propagate the energy. The one profile where reflections were obtained from the actual bedrock surface was the one at which the bedrock was a sandstone or sandy shale, and the thickness of bedrock above the limestone was much greater than at either of the other seismic sites. The results of this profile are shown in figure 4. This was one of three possible interpretations of the data originally made and the one best supported by sub-surface geologic data. Interpretation of the data of the other two profiles was not so ambiguous (fig. 5) but did not give a bedrock top.

HYDROLOGY

The State Water Survey analyzed a pumping test and other hydrologic data for the area (Walker, 1964), and the following section is largely based on the State Water Survey report.

Aquifer coefficients obtained from analysis of pump test data are:

Coefficient of transmissibility (T)	= 6,600 gpd/ft (gallons per day per foot)
Coefficient of permeability (P)	= 660 gpd/sq ft
Coefficient of storage (S)	= 0.10

The State Water Survey calculation of the practical sustained yield of the aquifer was based on a mathematical model of an aquifer 1000 feet wide, infinitely long, with an effective thickness of 10 feet and the coefficients of transmissibility, permeability, and storage given above. The coefficient of storage is indicative of water table conditions that will be obtained soon after pumping starts, owing to drawdown of the water surface below the aquitard. It was assumed the aquifer was bounded on the bottom and sides by impermeable material (barrier boundaries); the geologic data suggest that there is no direct permeable connection between the aquifer and the river.

The results suggest that the maximum quantity of water available is 147,000 gallons per day, or 102 gallons per minute (gpm), for a 200-day drought (average time between major periods of recharge in this part of Illinois) and 85,000 gpd (59 gpm) for a 730-day drought (severe 2-year drought conditions). These quantities are based on a 10-well system, each well 32 feet deep with 10 feet of screen, spaced 25 feet apart, and centered in the aquifer. The data also show that a single well system located at the site of the test well, not quite in the center of the aquifer, is capable of yielding 83,000 gpd (58 gpm) through a 200-day drought and 39,000 gpd (41 gpm) through a 730-day drought.

The geologic parameters utilized in obtaining the above figures consist of maximum possible dimensions for the aquifer system within the study area; therefore, actual potential yield may be somewhat lower.

As the minimum requirement for a supplemental ground-water supply was considered to be 1.5 mgd, this basin alone was judged inadequate to meet the demand.

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